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ITALIAN PETROLOGICAL SKETCHES.

V. SUMMARY AND CONCLUSION.

THE volcanoes which have been described in the preceding papers belong to the main Italian line which extends west of the Apennines from Tuscany to Naples, and which may be called the Bolsena-Vesuvius line. In a paper already quoted on the "Extinct Volcanoes of the Northern Apennines" de Stefani[1] calls attention to the fact that these volcanoes may be referred to two distinct types, distinguished not only by their structure, but by their eruptive rocks.

One type is that of the great strato-volcanoes, represented at Bolsena, Viterbo, Bracciano, and the Alban Hills, as well as at Rocca Monfina and Vesuvius farther south. The main structural features of these have been already noticed. Petrographically these strato-volcanoes are characterized by two features. In the first place leucitic rocks are very abundant at all of them, and form indeed their dominant and most characteristic feature. These are accompanied in most cases, not always, by non-leucitic rocks—ciminites and vulsinites, with exceptionally phonolite at Viterbo and toscanite at Bracciano. True trachytes are met with in abundance in the Vesuvian region and in small amount at Rocca Monfina, but elsewhere seem to be rare. Their second characteristic is the variety of eruptive products at each center, both among the leucitic and the non-leucitic rocks, as well as the abundance of tuffs. Though the variety be great, yet the rocks of each bear a great resemblance to those of the other centers, so much so that the whole line (including the centers of the second type) form an excellent example of a "petrographical province," and it is clear that the products of all the centers are related to each other genetically.

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[1] DE STEFANI, Boll. Soc. Geol. Ital., X, 449–555, 1891.

To the northwest of Bolsena and between the line of volcanoes just noticed and the coast are the eruptive centers forming de Stefani's other type. The most noteworthy are those at Campiglia, Rocca Strada, Monte Catini, Monte Amiata, Radicofani, Tolfa, and Cerveteri. These are all of relatively small extent, and are in general higher in proportion to their breadth than the strato-volcanoes. Some of them, as Tolfa and Cerveteri, were superfusive and apparently formed by domal eruptions of a pasty magma. Monte Amiata was probably a true strato-volcano.[1] According to Lotti[2] the Campiglic mass was laccolitic in character, being covered by arching Eocene beds. It is noteworthy that dikes, which are practically unknown elsewhere, are quite numerous here.

As de Stefani points out, these smaller eruptions differ from the large volcanoes in two important petrographical particulars. First, each individual mass is made up substantially of one kind of eruptive rock, the rock type at each being practically persistent throughout the mass. This persistency of type at each is in marked contrast with the great variety of products found at each of the strato-volcanoes. In the second place these smaller eruptions seem never to have produced leucitic rocks—at least none are known with certainty to occur as their products. They are uniformly non-leucitic and trachydoleritic, and extreme in type—either acid or basic. The rocks of Campiglia, Rocca Strada, Monte Amiata, Tolfa, and Cerveteri belong to the toscanites—acid trachydolerites with over 65 per cent. of silica with or without free quartz; while those of Radicofani, and probably also those of Monte Catini, are basic in character, with SiO_2 about or below 55 per cent., and belong either to the ciminites or the basalts.

TRACHYDOLERITES.

The intermediate potash-rich rocks which are found along the Bolsena-Vesuvius line carry *basic* plagioclase-labradorite to anorthite—along with orthoclase, and such rocks will be called collectively in this paper by the name of *trachydolerite*, a name proposed by Abich[1] as far back as 1841. This term seems the more appropriate since one of his type rocks is that of Monte Santa Croce at Rocca Monfina, which has the mineralogical characters of one of the subgroups with the chemical composition of another. For those intermediate effusive rocks in which the plagioclase occurring along with orthoclase is *acid*—andesine to oligoclase—the name *trachyandesite*,[2] which is in use in France, will be reserved.

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[1] DE STEFANI, Boll. Com. Geol. Ital., 1888, 223.

[2] LOTTI, cf. DALMER, Neu. Jahrb., 1887, II, 207.

Ciminite.—The rocks belonging to this group are porphyritic in structure, the phenocrysts being of augite, olivine, and sometimes feldspar, and the rather light to dark groundmass being seen under the microscope to be generally a holocrystalline paste of feldspar with augite and magnetite grains, glass base being rare. The lamprophyric habit of some of the specimens has been remarked on. The ciminites are characterized mineralogically by the presence of *alkali feldspar* and a *basic plagioclase, augite* and *olivine*, with accessory *magnetite* and *apatite*. Biotite and hornblende (especially the latter) are either entirely absent or only present in small amount. Chemically they are rather basic, silica varying from 54 to 57 per cent.; alumina is moderately high, as are the iron oxides; magnesia and lime quite high, respectively 3 to 6 and 5 to 9 per cent. Alkalis are low for the rocks of the region, but potash is uniformly higher than soda. These rocks do not seem to be very abundant, except at the Monti Cimini, where they apparently occur in large quantities.

In Table I are given all the reliable analyses of these Italian rocks which are known to the writer, together with those of the rocks of Radicofani. Of these No. 1 of the flow at Fontana di Fiesole, near Viterbo, may be regarded as typical. Vom Rath's analysis (No. 2) of a similar rock from the same region closely agrees with this, the chief discrepancy being found in the alkalies,

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[1] ABICH, Vulk. Erscheinungen, Brunswick, 1841, 100.

[2] This term has been used in a more general sense in the preceding papers.

TABLE I.

ITALIAN CIMINITES.

	1	2	3	4	5	6	7	8	9	10	11
SiO_2	55.44	58.67	56.32	56.76	56.42	57.95	57.73	54.83	55.00	53.63	55.23
Al_2O_3	18.60	15.07	18.17	16.79	16.81	12.52	17.85	20.17	14.38	14.17	14.06
Fe_2O_3	2.09	.....	2.23	2.07	3.26	.....	4.44	4.77	.....	1.46	5.06
FeO	4.48	8.35	6.47	6.95	6.92	5.44	3.90	3.86	9.29	8.07	4.12
MnO	.....	.....	.....	.....	0.23	1.70	.....	.....	.....	Trace	0.57
MgO	4.75	2.97	2.84	1.63	3.50	5.27	1.77	1.93	7.72	7.05	4.00
CaO	6.76	8.07	5.33	6.01	5.64	3.80	3.65	4.12	8.51	8.52	9.34
Na_2O.......	1.79	3.36	1.80	2.43	1.21	3.27	3.77	3.04	2.25	1.80	2.07
K_2O	6.63	3.50	4.18	4.67	3.07	4.78	7.65	7.38	2.52	2.03	2.43
H_2O	0.25	0.82	2.15	2.44	2.25	5.49	0.09	0.46	0.48	2.01	1.07
TiO_2	0.16	.....	.....	.....	.....	.....	.....	.....	.....	SO_3 0.62	SO_3 0.84
P_2O_5	Trace	.....	0.34	0.47	1.08	.....	Trace	.....	.....	0.93	1.33
	100.95	100.81	99.83	100.22	100.39	100.22	100.85	100.56	100.15	100.29	100.12
Sp. gr.	2.700	2.765	2.52	2.47	2.625	2.668	2.61	.....	2.808	2.79	2.683

NOTES TO TABLE I.

1. Fontana Fiesole, Viterbo, H. S. Washington anal., JOUR. GEOL., IV, 849, 1896.
2. West slope of Monte Cimino, vom Rath, Zeit. d. d. geol. Ges., XX, 304, 1868.
3. Mont' Alfina, Bolsena Region, Ricciardi anal., Klein, Neu. Jahrb. B. B., VI, 7, 1889.
4. Sassara, Bolsena Region, Ricciardi anal., Klein, *loc. cit.*, 7.
5. Monte Rado, Bolsena Region, Ricciardi anal., Klein., *loc. cit.*, 33.
6. Above Ortaccio, Campiglia, Tuscany, vom Rath, *loc. cit.*, 331.
7. L'Arso, Ischia, Fuchs, Tscher. Min. Mitth., 1872, 230.
8. Scoria, Le Cremate, Ischia, Fuchs, *loc. cit.*, 231.
9. Radicofani, vom Rath, Zeit. d. d. geol. Ges., XVII, 405, 1865.
10. Radicofani, doleritic variety, Ricciardi anal., Mercalli, *op. cit. post.*
11. Radicofani, andesitic variety, Ricciardi anal., Mercalli, *op. cit. post.*

which sum up about the same, but whose relative proportions are quite different. Ricciardi's two analyses of "olivine-bearing andesitic trachyte," Nos. 3 and 4, are quite typical, though the alkalies are rather low, as is generally the case in his analyses. These rocks evidently belong to the ciminites, as has been noted on a previous page.[1] It seems proper also to class with the ciminites the so-called augite-andesite of Monte Rado in the Bolsena region[2] on the strength of Ricciardi's analysis (No. 5), though it shows rather more iron and less alkalies than the first four. While Klein does not definitely speak of orthoclase as present, he refers the high potash either to the glass or to the presence of orthoclase or anorthoclase among the feldspar laths. No. 6 is of an "augite-porphyry" forming a dike at Campiglia, described by vom Rath, who says that "it does not agree with any rock heretofore described in petrography." It is porphyritic in structure, showing phenocrysts of orthoclase, plagioclase, augite, a little biotite and quartz, and quite abundant, generally serpentinized, olivines, which lie in a light to dark greenish gray groundmass. The rock examined was evidently much decomposed, but the analysis resembles in general those of the ciminites, though alumina is decidedly low.

Analysis No. 1 yields the following approximate composition:

[1] JOUR. GEOL., IV, 554, 1896.

[2] JOUR. GEOL., IV, 554, 1896.

Orthoclase,	39.4
Albite,	15.2
Anorthite,	22.8
Olivine,	10.2
Diopside,	8.7
Magnetite,	3.0
Accessory,	0.7
	100.0

I have also included among the ciminites, both on mineralogical and chemical grounds, the well-known "trachyte" of L'Arso on Ischia. This has long been known as an instance of the exceptional occurrence of olivine in trachyte, and has been taken by Rosenbusch[1] as the type of one subgroup of his "andesitic trachytes." Judging from an examination of a number of sections from specimens collected on the spot, plagioclase is not as abundant as in the Viterbo or Bolsena rocks. There are, however, some phenocrysts with multiple twinning lamellæ whose extinctions show them to be labradorite, Ab_1 An_1 or more basic; and a certain portion of the groundmass feldspar laths are of a similar plagioclase. Olivine, while present in my specimens, is not as abundant as at Viterbo, but a colorless diopside or augite is the prominent and abundant ferromagnesian constituent.[2] These observations agree with the analyses by Doelter of the main flow (No. 7) and of the scoria of the crater at Le Cremate (No. 8), which show less magnesia and lime and more alkali than in the typical ciminites.

Though we possess no reliable analysis of it, the so-called "biotite-trachyte" of Monte Catini in Tuscany may perhaps be regarded as closely related to the ciminites. Both orthoclase and a (basic ?) plagioclase are present and some pilite pseudomorphs after olivine are noted by Rosenbusch,[3] who also remarks upon its lamprophyric character. The rock is very remarkable for the abundance of olivine along with biotite.

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[1] ROSENBUSCH, Mikr. Phys., II, 773, 1896.

[2] I could find no traces of the leucite mentioned by vom Rath.

[3] ROSENBUSCH, Neu. Jahrb., 1880, 206, and Mikr. Phys., II, 764, 1896.

Closely related to the ciminites, if not to be classed with them, are the interesting rocks of Radicofani. This is a small hill a few kilometers east of Monte Amiata. The rock has been studied microscopically by Weiss,[1] Bucca,[2] and Mercalli.[3] Two varieties are to be distinguished—a doleritic and an andesitic. The former is dark gray to black, very compact and of specific gravity 2.79 (Mercalli). Augite, olivine, and feldspar phenocrysts are visible. Microscopically they resemble the dolerites, numerous large crystals of pale augite, olivine, and plagioclase (with a few of orthoclase, according to Mercalli), lying in a groundmass composed of microlites of plagioclase, magnetite, and apatite in a dark glassy base. The olivines in this rock are generally altered to fibrous green serpentine. The andesitic variety is light gray, of a trachytic aspect and specific gravity 2.683 (Mercalli). It shows phenocrysts of olivine. In thin sections are seen phenocrysts of plagioclase, orthoclase, augite, and olivine (the last altered to a reddish substance on the borders) lying in a groundmass of abundant feldspar microlites and magnetite grains, with a rather scanty yellowish glass base. It is seen that while the first variety is mineralogically a basalt, the second is a ciminite.

Three analyses of these rocks are given in Table I. Vom Rath's (No. 9) is of a specimen of the andesitic variety and is similar to those of Ricciardi. Ricciardi's (Nos. 10 and 11) differ from each other notably only in the silica, which is quite low in the doleritic variety though still higher than in normal basalts, and in the magnesia, which is extremely high in the more basic variety. Thus while the silica percentage is about that of the ciminites, alumina is decidedly lower (about that of the toscanites), iron higher, magnesia and lime very high, and alkalies low, but still higher than in normal basalts, and with potash above soda. From these analyses it seems probable that some of Bucca's and Mercalli's plagioclase is to be referred to alkali feldspar—perhaps triclinic, and also that the plagioclase must be either a basic labradorite or anorthite. These rocks may then be regarded as among the more basic members of the ciminites.

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[1] Cf. VOM RATH, Zeit. d. d. geol. Gesell., XVII, 405, 1865.

[2] BUCCA, Boll. Com. Geol. Ital., 274, 1887.

[3] MERCALLI, Atti. Soc. Ital. Sci. Nat., XXX, 1887.

We may finally allude briefly to the fact that at Rocca Monfina so-called basalts occur as products of the last phase of activity, and that there is reason for thinking that these rocks much resemble those of Radicofani and may be regarded as basic ciminites.[1]

Vulsinite.—The rocks belonging to this group are porphyritic in structure and megascopically look much like typical trachytes. Feldspar phenocrysts are especially prominent and with them are seen smaller crystals of augite and rare tables of biotite. The groundmass is light gray and in most cases is holocrystalline, or nearly so, glass being present in only small amount in the specimens examined. The feldspars comprise *orthoclase and soda orthoclase* and a *basic plagioclase*—labradorite to anorthite—in quite large amount. The ferromagnesian minerals are typically represented by *augite* or *diopside*, though *biotite* is accessory and is very abundant in some of the basic varieties. Hornblende is lacking at all the Italian localities examined, except for the occasional presence of sporadic crystals of barkevikite. *Magnetite* is generally present, but not in large amount. Both quartz and olivine are wanting, or only present sporadically.

The chemical composition of these rocks is shown in Table II.

They are rocks of medium acidity, the silica varying from 55 to 60 per cent., or perhaps somewhat over. Alumina and iron oxides are in about the same amounts as in the trachytes, magnesia somewhat higher, lime quite high (3 to 6 per cent.), and alkalies in the most representative rocks very high, with potash largely preponderating over soda. No. 1 may be regarded as the type analysis of a specimen from Bolsena. With this the analyses of vom Rath (No. 2) and Ricciardi (No. 3) agree fairly well, the greatest difference being in the alkalies. In No. 1 these are high, with potash greatly in excess of soda, while in vom Rath's their total amount is about the same but the relative quantities quite different, and in Ricciardi's they are both much lower than in No. 1, but with potash in excess. It may be remarked that these mutual differences are fairly constant elsewhere and point to differences in analytical methods rather than to differences in composition.

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[1] JOUR. GEOL., V, 1897.

Another typical vulsinite was found near Vetralla in the Viterbo region, and its analysis (No. 4) closely agrees with that of the Bolsena rock. The San Magno vulsinite (No. 5) is quite similar, though the silica is a little higher and the alkalies low. In regard to the rocks from Torre Alfina and San Lorenzo (Nos. 6 and 7) I must confess to some hesitation. Klein mentions olivine as occurring in notable quantity, though both analyses show small amounts of magnesia and high silica. The analyses resemble, indeed, much more those of the acid toscanites, and it seems probable that they were not made on the specimens examined by Klein. No. 8 is by Ricciardi of a specimen from the Piano delle Macinaje at Monte Amiata sent him by Verri.[1] The analysis is essentially that of a vulsinite. This view is confirmed by the description of Artini,[2] who states that it is gray, porphyritic, and composed of large phenocrysts of sanidine, smaller but more numerous phenocrysts of plagioclase, showing a core of bytownite, a border of andesine, with augite and biotite, lying in a groundmass of feldspar, augite, and glass.

Analyses 1 and 4 yield the following approximate compositions, though the results are uncertain, owing to our ignorance of the composition of the biotite and augite:

	1	4
Orthoclase,	49.5	44.3
Albite,	21.7	27.0
Anorthite,	14.4	14.1
Diopside,	6.4	3.2
Biotite,	3.4	4.8
Accessories,	4.6	6.6
	100.0	100.0

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[1] RICCIARDI speaks of it as labeled "the main mass of Monte Amiata." VERRI corrects this error later (Boll. Soc. Geol. Ital., VIII, 1889).

[2] ARTINI, Giorn. Miner., IV, 7, 1893.

TABLE II.

ITALIAN VULSINITES.

	1	2	3	4	5	6	7	8	9	10
SiO_2	58.21	59.22	57.97	57.32	60.03	63.22	63.26	59.73	55.69	55.08
Al_2O_3	19.90	18.56	17.65	19.85	17.05	16.26	16.05	16.79	19.08	17.25
Fe_2O_3	4.11	....	0.63	2.21	1.83	1.41	1.04	1.44	4.07	....
FeO	0.87	6.06	7.50	2.35	4.15	3.84	6.13	3.21	3.26	9.33
MnO	....	....	0.09	....	0.09	Trace	0.14	....	Trace	....
MgO	0.98	1.12	1.71	1.60	1.12	1.25	1.29	1.47	3.41	2.77
CaO	3.58	2.96	5.53	3.82	6.58	4.75	5.50	3.27	6.87	7.34
Na_2O	2.57	4.87	1.50	3.22	2.31	2.42	1.62	4.31	2.89	1.86
K_2O	9.18	6.66	5.31	9.15	5.12	4.18	3.18	6.09	4.41	5.32
H_2O	0.74	1.14	1.82	0.57	1.42	1.87	1.57	3.93	0.17	0.17
TiO_2	Trace	....	....	....	....	....	....	....	....	....
P_2O_5	Trace	....	0.42	....	0.42	1.07	0.51	....	....	....
	100.14	100.59	100.13	100.09	100.12	100.27	100.29	100.24	99.85	99.12
Sp. gr.	2.534	2.548	2.451	2.611	2.543	2.481	2.416		2.717	2.713

NOTES TO TABLE II.

1. Bolsena, H. S. Washington anal., JOUR. GEOL., IV, 552, 1896.
2. Bolsena, Vom Rath, Zeit. d. d. geol. Ges., XX, 291, 1868.
3. Bolsena, Ricciardi anal., Klein, Neu. Jahrb. B. B., VI, 8, 1889.
4. Vetralla, near Viterbo, H. S. Washington anal., JOUR. GEOL., IV, 849, 1896.
5. San Magno, Latera, Bolsena, Ricciardi anal., Klein, *loc. cit.*, 10.
6. Torre Alfina, Bolsena, Ricciardi anal., Klein, *loc. cit.*, 3.
7. San Lorenzo, Bolsena, Ricciardi anal., Klein, *loc. cit.*, 3.
8. Monte Amiata, Ricciardi, Gazz. Chim. Ital., XVIII, 1888.
9. Monte Santa Croce, Rocca Monfina, H. S. Washington anal., JOUR. GEOL., V, 252, 1897.
10. Monte Santa Croce, Vom Rath, Zeit. d. d. geol. Ges., XXV, 245, 1873.

In the last rock (9 and 10) we have an example of the mutual exclusion of biotite and olivine in the Italian and other trachydolerites, to which attention has already been called by Rosenbusch.[1] It is mineralogically a biotite-vulsinite, in that it is free from olivine, but chemically a ciminite, the silica being low and magnesia and lime high. The explanation of this peculiarity may be looked for in the complexity of the biotite molecule. It was pointed out by Iddings[2] that, since the biotite molecule may be regarded as made up of molecules of olivine $2(Mg, Fe)O, SiO_2$ and feldspathoid molecules of the form $(H, K)_2O. Al_2O_3. 2SiO_2$, under conditions where the complex biotite molecule would be unstable it would dissociate, resulting in the formation of crystals of olivine and of a potash-alumina silicate, either leucite or orthoclase, according to circumstances. This explanation has also been adopted by Bäckström[3] in the case of the leucite-basanites of Volcanello, he considering them to be the effusive forms of magmas which would appear intrusively as minettes or kersantites. The same idea has lately been alluded to by Pirsson,[4] who adds: "This process would of course find its most natural expression in magmas rich in magnesia and potash," which, it will be observed, is the character of the ciminite magma.

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[1] ROSENBUSCH, Mikr. Phys., II, 773, 1896.

[2] IDDINGS, Origin Igneous Rocks, Bull. Phil. Soc. Washington, XII, 166, 172, 1892.

[3] BÄCKSTRÖM, Geol. Fören. Stockh. Förh., XVIII, 155, 1896.

[4] PIRSSON, JOUR. GEOL., IV, 687, 1896.

Applying this idea to the rocks at hand it is evident that we may regard the olivine-bearing ciminites as formed from rather basic trachydoleritic magmas, rich in magnesia, which under other conditions of solidification would have assumed the form of biotite-vulsinites—thus adding another to the number of cases of magmas of the same chemical composition forming on solidification different mineral aggregrates. In this connection and as favoring this view of the dissociation of the biotite molecule may be mentioned the great paucity in biotite of all the leucitic rocks of Italy, and, it may be added, of the purely orthoclase-trachytes of Ischia. There seems to be, indeed, as demanded by the theory, a mutual exclusion of biotite and leucite. Olivine, it is true, is not very abundant in the leucitic rocks, except at Vesuvius, the magnesia generally entering into the pyroxene molecules, perhaps owing to the richness of the magma in CaO.

Toscanite.—The rocks belonging to this group are highly porphyritic and a glassy groundmass is often met with, though holocrystalline forms occur. They are characterized by the presence, along with the *alkali feldspar*, of a *plagioclase* which is rather more acid than in the preceding groups, generally varying from andesine to labradorite, though anorthite is found at Monte Amiata and elsewhere. The most constant and prominent ferromagnesian mineral is *biotite*, which is never wholly wanting, and at some localities, as at Campiglia and Rocca Strada, is the only colored constituent. In other places (Bracciano, Cerveteri, and Tolfa) *augite* or *diopside* is abundant along with the biotite; while again, as at Monte Amiata, *hypersthene* replaces augite as companion to the biotite. *Quartz* is often present, either in well-shaped crystals or as anhedra, but olivine is never found. *Magnetite* is rare or absent. Silica is much higher than in the other groups, varying from 65 to 73 per cent., alumina and iron are low, magnesia and lime high considering the acidity, and the alkalies also high, with potash higher than soda. We may then regard the toscanites as acid *biotite-trachydolerites*, and the rocks of Bracciano, Cerveteri, and Tolfa would be *augite-toscanites*, while those of Monte Amiata would be *hypersthene-toscanite*, if such a subdivision be deemed advisable.

In Table III are given the best analyses of the representative Italian toscanites. Those from Bracciano, Cerveteri, and Tolfa (Nos. 1, 2, 3, 4, and 5) have been already described. Attention need only be called to the richness of the San Vito rock in Na_2O relative to K_2O, as shown by Dr. Röhrig's analysis, and confirmed by mine made later. In this respect it is notable among the rocks analyzed by me. The rocks of Monte Amiata, whose composition is given in No. 5, have been so fully described by J. F. Williams, that the reader is referred to his paper.[1] The rocks of Campiglia and Rocca Strada, Nos. 7, 8, 9, and 10, are purely biotite-toscanites and are all quartz-bearing. It will be observed that the pyroxene-bearing toscanites (1–6) are notably less acid than those which carry only biotite.

Trachydolerites elsewhere.—Having thus reviewed the main feature of the trachydolerites along the Bolsena-Vesuvius line, it will be of interest to see if such rocks are found elsewhere. Their geographically nearest counterparts are found in the Lipari Islands where vulsinites and ciminites occur according to the descriptions of Sabatini[2] and Mercalli.[3] It must be noted, however, that these are not very abundant and are associated with true rhyolites, andesites, and basalts, and not with leucitic rocks. Some of the rocks of Monte Ferru in Sardinia and of the Ponza Islands may also belong to this group, though there is doubt as to the character of the plagioclase, and they may be rather trachyandesites. Another example of such transition rocks is found at the Azores, where Hartung[4] in 1860 noted the presence of rocks intermediate between the trachytes and the basalts, which he called by Abich's name of trachydolerite. The later investigations of Mügge[5] have established the presence of such rocks, though we are again left in doubt as to the char-

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[1] J. F. WILLIAMS, Neu. Jahrb. B. B., V, 403 ff., 1887.

[2] CORTESEE SABATINI, Isole Eolie, Rome, 1892.

[3] MERCALLI, Giorn. Min., III, 97, 1892.

[4] HARTUNG, Die Azoren, Leipzig, 1860, 291, 319.

[5] MÜGGE, Neu. Jahrb., 1883, II, 201.

TABLE III.

ITALIAN TOSCANITES.

	1	2	3	4	5	6	7	8	9	10[1]
SiO_2	64.57	64.04	66.24	65.19	67.61	65.05	70.64	69.90	71.14	73.00
Al_2O_3	16.80	14.48	15.64	16.04	14.04	16.22	14.11	14.73	11.14	14.45
Fe_2O_3	0.97	1.73	1.16	1.16	....	1.01	....	....	....	....
FeO	3.02	4.35	2.19	2.48	5.40	2.48	2.86	2.90	2.73	3.12
MnO	Trace	....	....	....	....	Trace	....	....	Trace	Trace
MgO	1.69	1.03	0.89	0.99	0.65	1.46	0.72	0.72	1.62	0.82
CaO	3.53	4.00	2.17	2.92	3.71	3.19	2.02	1.91	3.17	3.30
Na_2O	3.81	4.14	2.05	2.26	5.50	2.62	4.67	4.30	1.40	1.70
K_2O	4.01	3.65	6.60	6.11	2.41	5.52	2.95	3.01	4.13	3.18
H_2O	1.28	2.06	3.25	1.85	2.28	1.60	2.30	2.10	1.77	0.70
TiO_2	....	0.28	....	....	....	0.44	....	....	0.00	Trace
P_2O_5	....	....	....	....	....	Trace	....	....	Trace	Trace
SO_3	....	....	....	....	....	0.11	....	....	1.78	Trace
Cl	....	....	....	....	....	0.04	....	....	Trace	Trace
X	....	....	....	....	....	0.59	....	....	1.05	Trace
	99.68	99.76	99.00	100.33	101.60	100.33	100.27	99.57	99.83	100.27
Sp. gr.	2.542	2.542	2.455	2.509	2.537	....	2.478	....	2.480	2.76

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[1] Contains also traces of Li_2O, B_2O_3, and CO_2.

NOTES TO TABLE III.

1. Monte San Vito, Bracciano, H. S. Washington anal.
2. Monte San Vito, Bracciano, A. Röhrig anal., JOUR. GEOL., V, 49, 1897.
3. Monte Cucco, Cerveteri, H. S. Washington anal., JOUR. GEOL., V, 49, 1897.
4. Castle Hill, Tolfa, H. S. Washington anal., JOUR. GEOL., V, 49, 1897.
5. Tolfa, vom Rath., Zeit. d. d. geol. Ges., XVIII, 596, 1866.
6. Monte Amiata, mean of 7 analyses, J. F. Williams, Neu. Jahrb. B. B., V. 446, 1887.
7. Campiglia, Tuscany, vom Rath, *loc. cit.*, 640.
8. Campiglia, Dalmer, Neu. Jahrb., 1887, II, 213.
9. Sassoforte, Rocca Strada, Matteucci, Boll. com. geol. ital., 285, 1890.
10. Torniella, Rocca Strada, Matteucci, Boll. soc. geol. ital., X, 677, 1891.

acter of the plagioclase. Some of the analyses by Bunsen which Hartung gives are very similar to those of Tables I and II and indicate that it is basic. It is probable that similar rocks occur on Madeira,[1] and Renard[2] describes andesitic trachytes from Teneriffe and Ascension which may also belong here.

A group of rocks apparently resembling the Italian trachydolerites from near Buda-Pesth is described by A. Koch[3] as "labradorite-trachytes." They are composed of augite, hornblende, and biotite, and occasionally garnet, with labradorite (analyzed) as phenocrysts, and orthoclase only in the groundmass. The analyses much resemble those of the Italian trachydolerites, silica ranging from 52 to 67 per cent. and lime from 7 to 2, though magnesia is very low. Alkalies are much lower on the whole, but still higher than in normal andesites, and with potash predominating over soda.

The most interesting group, however, to compare with the Italian rocks is that of the absarokite-banakite series from the Yellowstone Park recently described by Iddings,[4] the rocks of which closely resemble those of the ciminite-toscanite series. The American rocks are similarly characterized by the presence of orthoclase and labradorite, with augite as the most prominent ferromagnesian mineral. The frequent occurrence of borders of orthoclase around labradorite cores is also noteworthy; a feature which we have met with so often in the Italian rocks. The most basic of them — the absarokites with silica from 47 to 52 and very high magnesia and lime — carry olivine, as do the more acid shoshonites with silica from 50 to 56; these latter correspond to the Italian ciminites. The last of the series — the banakites with silica from 51.5 to 61 — carry no olivine, and more biotite than augite, and are rather poor in ferromagnesian minerals; these would correspond to some of the vulsinites. It is especially worthy of note that in these last rocks "augite and olivine are more or less completely replaced by biotite" — the same mutual exclusion being observed here that we find in Italy. Chemically the absarokites are much more basic, while the analyses of the shoshonites and banakites closely approximate to those of the ciminites and vulsinites, except in the alkalies.

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[1] HARTUNG, Madeira und Porto Santo, Leipzig, 1864.

[2] RENARD, Petrology of Oceanic Islands, London, 1890, 7, 23.

[3] KOCH, Zeit. d. d. geol. Gesell., XXVIII, 293, 1876.

[4] IDDINGS, JOUR. GEOL., III, 935, 1895.

The similarity is indeed so great that the ciminites might with propriety be called shoshonites, and the vulsinites banakites. But there are certain considerations which seem to render such a course inadvisable. The difference in the alkalies has been already mentioned. While in the Italian rocks they are high and with potash very largely preponderating over soda, in the American rocks they are rather lower, and soda, while always lower in percentage, is much closer to the potash and molecularly often surpasses it. In Italy again we find the acid toscanites which are not represented at the Yellowstone Park, while at the latter we have the absarokites and nothing corresponding to them in acidity among the trachydolerites of Italy. The center of acidity, so to speak, at the Yellowstone Park seems to lie quite low, while in Italy it is much higher. Furthermore the great abundance of leucite at the Italian volcanoes is unparalleled in the American district, where the absarokite-banakites are genetically related to normal andesites and basalts, though leucite occurs to a small extent.[1] From these facts we are led to believe that the parent magma of the Italian rocks was not only more acid than at the Yellowstone, but was preëminently a potash magma, which is certainly not true of the other. It may be added that the occurrence of two such well-marked and generally similar series of orthoclase-plagioclase rocks at widely distant localities forms a strong argument for the recognition of such types in accordance with Brögger's views.

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[1] ROSENBUSCH, in the last edition of his Mikroscopische Physiographie (II, 1216, 1896), describes these rocks in connection with the leucite-tephrites.

Correlation of the trachydolerites. — Before passing on to the leucitic rocks it will be as well to examine the relationships of the trachydolerites and see what their position is in regard to other rocks of our classification. Brögger has so ably presented the arguments for the recognition of intermediate types that nothing need be added on that score, since all the arguments advanced by him for the recognition of the monzonites as an independent group of the same rank as the syenites and diorites apply with equal force to the trachydolerites and trachyandesites. The chief objection which may be brought against such ideas is that their acceptance would tend to "overburden petrological literature with new names." This is undoubtedly true to some extent, and many, perhaps most, of these names might be but temporary in their use, but they would yet fulfill their legitimate object of enabling us to comprise a given set of characters in one word, make our ideas of the various rock types more clear and precise, and thus lead us toward the solution of that vexed question — a rational and generally accepted classification of rocks, such as is found in the organic sciences.[1] The law of the survival of the fittest would hold good here as in animate nature. The needless names and types will be gradually discarded, and on what is left we may build a nomenclature of which the terms will be concordant both with each other and with the facts of nature, whenever the broad principle underlying the relationships of rocks shall have been discovered,

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[1] In these, by the way, names are far more numerous than in petrology, and it may be added that it would seem that the advantage of having well-defined types would outweigh the disadvantage of putting a little greater tax on our memories.

TABLE IV.

	Trachyte Series		Trachyandesite Series		Trachydolerite Series		Andesite Series		Basalt Series	
	Alkali-feldspar rocks		Alkali-feldspar and acid plagioclase rocks		Alkali-feldspar and basic plagioclase rocks		Acid plagioclase (andesine-oligoclase) rocks		Basic plagioclase (labradorite-anorthite) rocks	
Acid	SiO_2 *ca.* 67–80	Liparite Rhyolite Quartz-Pantellerite	SiO_2 *ca.* 65–75	Iceland Liparites Vulcanite	SiO_2 *ca.* 64–75	Toscanite Dollenite?	SiO_2 *ca.* 61–70	Dacite	SiO_2 *ca.* 60–70	Santorinite
Medium	SiO_2 *ca.* 60–66	Trachyte Pantellerite	SiO_2 *ca.* 60–65	Domite Siebengebirge and Euganean Trachytes	SiO_2 *ca.* 60–64	Acid Vulsinite and Banakite	SiO_2 *ca.* 55–61	Andesite	SiO_2 *ca.* 52–60	Labradorite (of Fouqué and Michel-Lévy)
Basic	SiO_2 *ca.* 50–60	? ?	SiO_2 *ca.* 50–60	Basic Auvergne Trachytes	SiO_2 *ca.* 50–60	Vulsinite Banakite Ciminite Shoshonite Absarokite	SiO_2 *ca.* 45–55	Basic Andesite	SiO_2 *ca.* 43–52	Basalt Olivine-Basalt

as the doctrine of evolution now underlies the classifications of zoölogy and botany.

It is through considerations of this sort that I have felt justified in proposing the new names in the preceding pages, and that I sketched the following brief outline of a grouping of the feldspathic effusive rocks. In Table IV Brögger's idea is carried out, and furthermore the two main divisions of the lime-soda feldspars—the basic and the acid—are recognized. The reasons for the rehabilitation of an earlier system of classification[1] need not be gone into here, since the scheme represented is not proposed for general adoption, but only for the purpose of showing the relationship to well-established types of such rocks as those of the absarokite-banakite series and the ciminite-toscanite series.

In Table IV, then, the rocks included are classified by their dominant feldspars and by their silica content. In the first column we find the *trachytic series*, which includes only the purely or predominantly alkali feldspar rocks. These include the rhyolites (both of the potash and soda series) and the quartz-pantellerites; the trachytes proper, such as those of Ischia, Berkum, and Algersdorf, and the pantellerites; while the most basic members of this series are unknown at present, or perhaps incapable of existence, their place being taken by certain leucitites.[2] The *trachyandesitic series* would embrace those containing alkali feldspar and acid plagioclase (oligoclase-andesine) in approximately equal amounts. Their most acid representatives would include such rocks as the Icelandic rhyolites described by Bäckström[3] and the vulcanite of Hobbs;[4] those of medium acidity include what are called oligoclase-trachytes, and are typically represented by the *domite*[5] of the Auvergne and many trachytes of the Siebengebirge; while their more basic members

[1] Cf. J. ROTH, Gesteinsanalysen, Berlin, 1861.

[2] They would represent chemically and mineralogically in an effusive form the basic augite-orthoclase *shonkinite* of Weed and Pirsson. (Bull. Geol. Soc., VI, 415, 1895.)

[3] BÄCKSTRÖM, Geol. Fören. Stockh. Förh., XIII, 637, 1891.

[4] HOBBS, Bull. Geol. Soc., V, 598, and Zeit. d. d. geol. Ges., XLV, 578, 1893.

[5] This might be used as the name for the group of medium acidity.

are found in many of the trachyandesites of the Auvergne described by von Lasaulx[1] and Fouqué.[2] Many of the rocks of the Euganean Hills also belong here. The series of *trachydolerites* has been already described. The *andesitic series* would include the dacites and andesites, with their definitions narrowed to their original limits,[3] so as to include only the rocks whose feldspars are acid plagioclase—oligoclase to andesine. In the *basaltic series*, carrying only labradorite and anorthite, we find the most acid members well represented by the "pyroxene-andesites" of Santorini, the greater part of whose feldspars have been shown by the researches of Fouqué[4] to be basic plagioclase. These have a high percentage of silica (65 to 69), and for convenience such rocks might be called *santorinites.* In the moderately acid part of the series would be found rocks corresponding to many of the labradorites of French petrographers, as well as many rocks classed as basalts, but which are more acid than the normal, such as those of the Löwenburg, Meissner, and the Vogelsberg. These may or may not carry olivine, as is also the case with the intermediate and basic trachydolerites and andesites. Toward the basic end we would have the basalts proper, chiefly anorthite-bearing and with or without olivine; while below these would come such rocks as the limburgites and augitites.

It will be seen from the above that the trachytes are rich in alkalies and poor in lime; the trachyandesites rather rich in potash and also in soda and lime; the trachydolerites rich in potash and lime, but poor in soda; the andesites rich in soda and lime, but poor in potash and the basalts very rich in lime and poor in alkalies, especially potash.

A somewhat similar table is given by Fouqué and Michel Lévy on page 155 of their Minéralogie Micrographique (Paris, 1879). The effusive rocks are divided according as they contain alkali feldspar, oligoclase, labradorite or anorthite, and these groups are subdivided according to their ferromagnesian minerals, biotite, hornblende, or pyroxene. Neither trachyandesites nor trachydolerites are mentioned.

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[1] VON LASAULX, Neu. Jahrb., 1870, 1871, 1872.

[2] FOUQUÉ, Étude des Feldspaths, Paris, 1894, 254–270.

[3] ROTH, Gesteinsanalysen, Berlin, 1861, p. XLV. VON HAUER und STACHE, Geologie Siebenbürgens, 1863, 70, 79.

[4] FOUQUÉ, Santorini et ses Eruptions, Paris, 1879; also Étude des Feldspaths, 317–320. The smaller groundmass microlites are more acid.

It must also be noted that a somewhat similar scheme was proposed by H. O. Lang[1] in 1891 and carried out by him in great detail. He bases his purely chemical classification entirely on the relative proportions of the percentages of lime, soda, and potash, neglecting the other components and the mineralogical composition, so that the present grouping and his differ distinctly from each other.

LEUCITIC ROCKS.

Comparatively little can be said of these rocks here, since detailed descriptions of many of them have been already given, and since a proper treatment calls for more space than is available. As regards classification, while they are on the whole sharply separated from the trachydolerites, yet *inter se* they grade into each other to such an extent that the discrimination of definite types is more than usually difficult and subjective in character.

It will also have been evident from the descriptions given that many of the varieties described differ from the types generally accepted. Thus those rocks which have been called leucite-phonolite for want of a better name contain only a small amount of nepheline and are quite distinct from the typical German leucite-phonolites. The unfortunate difference of opinion as to the use of the terms leucite-trachyte and leucite-phonolite has been noticed, and in other ways the need is made evident of some general revision of all this group of important rocks. At present, however, the material is not at hand for such an attempt, which it is hoped will be undertaken later; and the names used are to be regarded as provisional only, and the whole group of leucitic rocks as the subject of future investigation. In Table V, only a few of the many analyses are given,

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[1] H. O. LANG, Min. Petr. Mitth., XII, 199, 1891.

TABLE V.

ITALIAN LEUCITIC ROCKS.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SiO_2 ..	45.93	47.89	48.89	49.03	47.82	47.40	49.73	50.24	52.16	55.11	55.87	55.85	55.10	55.17	55.21	55.26	58.48	59.51
TiO_2 ..	.....	0.77	.....	.....	.....	0.30	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.36	.....	.....
Al_2O_3	18.72	18.25	16.05	15.18	18.85	19.84	19.20	20.09	15.03	16.07	21.82	19.31	19.20	20.49	19.81	16.36	19.56	18.89
Fe_2O_3	.....	4.93	1.80	2.07	5.24	2.72	5.50	2.54	3.17	3.04	2.34	3.77	.....	3.27	2.69	5.76	.....	.....
FeO ..	10.68	3.64	10.09	6.32	5.12	4.40	2.41	5.65	8.42	8.46	1.10	1.88	6.86	2.74	2.86	2.90	4.99	5.26
MnO ..	.....	Trace	0.43	0.19	.....	.....	Trace	Trace	0.24	.....	Trace	Trace	.....	Trace	.....	.....	.....	Trace
MgO ..	5.67	3.68	3.98	6.05	4.40	4.23	2.63[2]	3.65	4.69	3.10	0.48	1.73	1.18	1.58	1.68	1.14	0.53	1.50
CaO ..	10.57	8.70	11.88	12.58	9.51	9.88	7.96	7.83	10.07	6.46	3.07	3.84	3.75	3.73	4.61	3.90	2.60	1.90
Na_2O .	1.68	2.60	1.81	1.49	2.65	2.93	1.99	2.97	2.38	1.58	4 81	3.39	2.68	2.27	3.13	4.08	3.14	4.99
K_2O ..	6.83	8.23	3.00	4.07	6.41	5.91	9.39	7.45	2.47	5.07	10.49	8.77	10.78	9.58	8.45	8.82	10.47	7.25
H_2O ..	0.59	0.65	1.39	2.09	.....	1.66	1.19	0.36	0.72	0.89	0.34	1.14	1.22	0.99	0.99	1.20	0.24	0.56
P_2O_5 .	.....	.....	0.29	0.86	.....	.....	.....	.....	1.15	0.75	.....	.....	.....	.....	.....	.....	.....	.....
	100.67	99.34	100.19[1]	99.93	100.00	99.27	100.00	100.78	100.50	100.53	100.32	99.68	100.77	99.82	99.43	99.78	100.01	100.05[3]
Sp.gr.	.....	2.781	2.811	2.743	.....	.....	2.655	.....	2.749	2.546	2.557	2.648	2.501	.....	2.609	.....	2.572	2.603

[1] Also 0.59 SO_3.

[2] By difference.

[3] Also 0.19 Cl.

NOTES TO TABLE V.

1. Leucitite, Capo di Bove, Bunsen anal.
2. Leucitite, Crocicchie, Bracciano, Washington anal.
3. Leucitite, Sassi Lanciati, Bolsena, mean of 2, Ricciardi.
4. Leucite-basanite, Toscanella, Bolsena, Ricciardi.
5. Leucite lavas, Vesuvius, mean of 49 anals., Roth, Geologie, II, 268.
6. Leucite-tephrite, Rocca Monfina, Röhrig.
7. Leucite-tephrite, Bracciano, Washington.
8. Leucite-tephrite, Monte Cavallo, Bolsena, Washington.[1]
9. Leucite-tephrite, Monte Bisenzio, Bolsena, Ricciardi.
10. Leucite-tephrite, Montalto, Bolsena, Ricciardi.
11. Leucite-phonolite, Lake Bracciano, Washington.
12. Leucite-phonolite, Bagnorea, Bolsena, Washington.[1]
13. Leucite-phonolite (?) Bolsena, Vom Rath.
14. Leucite-trachyte. San Rocco, Mte. Vico, Washington.[1]
15. Leucite-trachyte, Monte Venere, Viterbo, Washington.
16. Leucite-trachyte, Madonna di Lauro, Viterbo, Röhrig.
17. Leucite-trachyte (?), Monte. S. Antonio, R. Monfina vom Rath.
18. Leucite-trachyte, Viterbo, vom Rath.

the most representative being selected. Many more must be made before these rocks can be adequately treated from a chemical standpoint.

By far the best defined type is that of the so-called *leucitites*, which are quite constant in structure and mineralogical composition, as already described. The chemical composition of typical leucitites is given in Table V, Nos. 1, 2, and 3. They are very basic rocks, with high iron and lime, quite high magnesia, and high alkalies. *Leucite-basalts* seem to be quite unknown in the Italian localities—perhaps owing to the richness of the magma in lime, which makes a basic plagioclase-free rock almost an impossibility if any of the MgO is withdrawn from a possible diopside molecule to form olivine. Outside of the Vesuvian region, where they occur in abundance, *leucite-basanites* are only met with in small amounts. Their analyses (Nos. 4 and 5) resemble those of the leucitites except that they are higher in magnesia and iron as well as in lime, and those of Bolsena low in alumina. The *leucite-tephrites* form a group which is one of the most difficult to classify satisfactorily owing to the large number of transition forms toward the leucitites on the one hand and the leucite-trachytes on the other. In general they are characterized by a rather doleritic micro-structure and the plagioclase is basic; chemically they are very basic in character, their silica content scarcely running above 50 per cent. Leucite-tephrites of this type abound at Bolsena, Rocca Monfina, and Vesuvius, and typical analyses are represented by Nos. 6, 7, and 8. Other leucite-tephrites occur whose silica content is higher. Examples are the rocks of Montalto (No. 10), in which Klein reports the feldspar as anorthite, and that of Monte Bisenzio (No. 9). Such acid leucite-tephrites, however, have not come under my own observation, and the high silica is to be explained by the presence of considerable orthoclase. Indeed my observations and such analyses as I have been able to make lead me to think that a typical Italian leucite-tephrite (which is poor in orthoclase) has a silica percentage of 50 or less, and that the plagioclase is generally, if not normally, a basic one.

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[1] Made since publication of their respective papers.

When we reach the *leucite-trachytes* and *leucite-phonolites* we find a decidedly more acid group of rocks with silica ranging from 55 to 59. These shade off into the leucite-tephrites to some extent, but on the whole are distinctly separated from them. Of leucite-trachyte we have few analyses, Nos. 14–18 being the only reliable ones known to me. They show high alumina, low magnesia and lime, and high alkalies—especially potash, though this last feature is perhaps not as marked as we might expect. The analyses of leucite-phonolite (Nos. 11, 12, 13) resemble these very closely, though soda is somewhat higher, and are quite different from those of leucite-phonolites from Germany,[1] which are much more basic and with soda much higher than potash. Indeed, so great is the resemblance to analyses of leucite-trachyte that these Italian leucite-phonolites ought properly to be called nepheline-bearing leucite-trachytes. They all carry orthoclase in large amount, especially in the groundmass, and nepheline occurs as the last product of crystallization. Only one case of a purely leucite-nepheline rock was observed, that at the Asteria di Biagio, near Orvieto.[1] It may be noted here that in all these leucitic rocks the dominant feldspars are orthoclase and a basic plagioclase, that augite and diopside are the prevailing ferromagnesian minerals, that both biotite and hornblende are rare, and that they are rich in potash and also in lime. They thus resemble in their broad features the non-leucitic rocks—apart from the presence of leucite.

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[1] ZIRKEL, Lehrbuch, II, 465, 1894.

Turning to Table V it will be observed that there is a break in the silica percentages between 50 and 55. Below the former are the leucitites, leucite-basanites, and most of the leucite-tephrites; between the two very few analyses are seen, while between 55 and 56 there is a large number of analyses, and above this last a much smaller number, with silica running up to nearly 60, which is the extreme figure for leucitic rocks. This feature is best seen when all the analyses available are tabulated. Space considerations prevent this being done here, but the break between 50 and 55 is very evident. The number of analyses represented is so large, and covers so many varieties of rock, that this clustering of the silica about 49 and 56 may be reasonably assumed to exist in fact and not to be due to chance in the selection of analyzed material, as might well be the case with few analyses. We may note also in the analyses of Table V that, while alumina is somewhat variable, it is in general higher in the basic group than in the more acid, as is also true of iron oxides Lime and magnesia show the greatest differences, there being more than double the amount of them in the basic than in the acid group. There is less difference to be observed in the alkalies, they being very high in both groups, but perhaps more so in the acid one.

Comparison of the trachydolerites and leucitic rocks.—The general similarity of the two groups has already been noticed, and it is further of great interest to observe, on referring to Tables I, II, and III, that a clustering of the analyses about definite points is to be found in the analyses of the trachydolerites as well as in those of the leucitic rocks. The ciminites and vulsinites reach no higher than 60 per cent. of silica, and lie in general between 55 and 58 per cent., while the toscanites are no lower than 64 per cent., and are in general much higher. Corresponding differences may also be noted in the other constituents, especially Fe_2O_3, FeO, MgO and CaO. It is also seen that transitional chemical forms are of limited occurrence, though the analyses are not as numerous as in the leucitic group. The analyses, then, of both groups are clustered about certain points and do not form a gradual series from the most basic to the most acid, as Brögger understands a series to be constituted. A similar clustering of the analyses may be seen at such volcanic localities as the Yellowstone Park, Montana, Cape Verde Islands, and Ægina and Methana; and the study of complete series of analyses would probably reveal the same state of affairs elsewhere. Indeed the fact may be said to be generally known, though perhaps not definitely formulated. An explanation which may be suggested is that this clustering of analyses is due to a quite complete course of differentiation, assuming the correctness of the differentiation hypothesis.

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[1] JOUR. GEOL., IV, 558, 1896.

Each main group of rocks, therefore, may be subdivided chemically, and mineralogically to a certain extent, into two subgroups (classing the ciminites and vulsinites together), a basic and an acid. Further, while the leucitic subgroup is more basic in each case than the corresponding trachydoleritic one, yet the variations in each are similar. These are best seen on tabulating the means of the best of the various preceding analyses. It is scarcely worth while to do so in this place, but the main features may be briefly pointed out. There is a difference in each case of 8 to 10 per cent. of silica; and iron, magnesia, lime, and to a less extent alumina, are higher in the basic group, while alkalies show less regularity. The molecular ratio of soda to potash varies in my separate analyses from .3 to 1.2, being fairly constant (.5 to .6) in the leucitic groups, and with higher soda at the extremes of the trachydolerites. It is probable that with more numerous analyses the resemblances would be even greater since there are indications of a division of the basic leucitic subgroup into two divisions corresponding to the ciminites and vulsinites. These would include on the one hand the leucitites and leucite-basanites, and on the other the leucite-tephrites. There exist then along the Bolsena-Vesuvius line at least two well-defined series with correlated members in each, the Ciminite-Vulsinite-Toscanite Series and the Leucitite-Leucite-tephrite-Leucite-trachyte Series. These two resemble each other very closely, except for the presence of leucite in the latter and the uniformly greater basicity of the correlated members of this series as compared with those of the former. There also occurs a typically trachytic group in the Vcsuvian region, while the phonolites of Viterbo mineralogically stand apart, but chemically are related to the leucite-trachytes. These series are, however, not gradual in Brögger's sense of the term,[1] but form related but separated groups of rocks.

Differentiation of the magma.—The question of the process or processes of differentiation and the composition of the parent magma is of great interest, but needs far more detailed and extensive knowledge of the regions involved and of the rocks than is yet available. The question is somewhat complicated by the presence of leucite in such large amounts, and by the fact already noted, that it is possibly derived from a potential biotite molecule, or at least that some connection seems to exist between the two minerals. It is pretty generally believed that leucite is essentially an effusive mineral, though some cases of intrusive leucitic rocks are known. Therefore, although the first impulse is to consider the leucitic rocks as distinct differentiation products from the trachydolerites, yet caution must be used, since it seems possible that their differences are due rather to differing conditions of extrusion than to differing secondary magmas. This, of course, would not be true in all cases, since leucite would be formed in a potash-rich magma poor in silica, while orthoclase would take its place in one more acid. This is seen clearly in the rocks with silica below 55 which are almost uniformly leucitic, while those with silica above 60 are as uniformly leucite free and orthoclase bearing. It is in the intermediate group with silica from 55 to 60 that we must look for evidences of the connection of leucite with extrusive conditions. These magmas are apparently in a nicely balanced chemical condition, which needs only a comparatively slight change of conditions to throw them into the one mineralogical group or the other. It is known that the leucitic rocks are almost invariably met with as flows, while the trachydolerites more frequently take the form of domal extrusions; that the leucitic rocks are the products of later eruptions, on the whole, than the trachydolerites except at Rocca Monfina; and that they have been ejected at central vents while the trachydolerites are more generally peripheral. This is suggestive of the idea that leucite has been formed in place of orthoclase during the simmering of the magma in the throat of the volcano under low pressure,[1] while the peripheral orthoclase magmas were partially crystallized under greater pressure.

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[1] BRÖGGER, Grorudite—Tinguait Serie, Kristiania, 1895, 169.

In view of the above facts and those given in the preceding section I am inclined to think that the two main groups of rocks which are found along the Bolsena-Vesuvius line do not represent two distinct primary differentiation products, but that their differences are due to diverse conditions of extrusion, solidification, and the like, these conditions being, of course, secondary to the chemical character of the differentiation products, as has just been explained.

In regard to the character of the parent magma we may feel confident that it was very rich in potash and lime,[2] basing our judgment on the preceding descriptions and analyses. More than this we cannot postulate with any degree of certainty, but its general composition is perhaps shown by the mean of the extreme differentiation products—the toscanites and basic leucitic rocks—or by the mean of the ciminites, vulsinites, and acid leucitic rocks, which closely resemble each other. On such a basis we could suppose it to have approximately a composition as follows: $SiO_2=57–58$, $Al_2O_3=17–18$, total iron oxides as $FeO=6–7$, $MgO=2–3$, $CaO=5–6.5$, $Na_2O=2–2.5$, $K_2O=7–8$, $H_2O=1–1.5$ per cent.

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[1] Cf. BÄCKSTRÖM, op. cit., p. 163; also LACROIX, op. cit., 637 ff.

[2] The hypothesis advanced by LAVIS (Natural Science, IV, 138, 1894) that the large amount of lime is due to absorption (osmosis) from the subjacent limestone traversed by the magma must be mentioned, though the writer can only admit its influence in a most limited way, if at all. The researches of Brögger and Pirsson have shown conclusively that it does not hold good elsewhere, and various considerations, which need not be gone into here, lead me to minimize its effect in Italy also.

Whether the original magma differentiated horizontally from north to south we are not yet in a position to discuss, but at each center we may suppose the body of magma to have been quite completely differentiated. We would thus have the toscanites and the basic leucitic rocks (leucitites and leucite-basanites) representing the extreme products—the oxyphyric[1] and lamprophyric types, respectively. Apart from questions of conditions of solidification, the absence of leucite in the vulsinites may be explained by their higher silica,[2] while in the ciminites and biotite-vulsinites the high magnesia conditioned the formation of olivine, leaving the remaining part of the magma sufficiently acid for the formation of orthoclase rather than leucite. That these suppositions are possible may be seen on comparing analyses 1, 4, and 9 of Table I and 1 of Table II, with 11, 12, 14, and 15 of Table V, which are practically identical except for the silica in the first two, and the magnesia in the second two of the trachydolerites.

All this is, however, admittedly speculative to a large extent, and these views are advanced in a provisional way to be tested, and perhaps greatly modified, by future investigations. Finally, it has perhaps have been noticed that little or no reference is made to the succession of the rocks. The omission is intentional, because it does not seem to the writer, even granting that the order of eruptions is of the importance often attributed to it, that our knowledge of the subject along the Bolsena-Vesuvius line is sufficient to be of much value.

HENRY S. WASHINGTON.

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[1] PIRSSON, Am. Jour. Sci., L, 118, 1895.

[2] The anomalous acid leucite-tephrites observed by vom Rath and Ricciardi are against this view, and some of them need confirmation.